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GAS INTRODUCTION DEVICE FOR LOW-PRESSURE CVD AND METHOD FOR MANUFACTURING SAID DEVICE

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Claims

1. A gas introduction device for low-pressure CVD in which raw material gases, which are introduced from multiple pipes for transporting different types of gases into a vacuum chamber maintained at a low pressure, either through a wall surface of said vacuum chamber or through a fixing element provided on the vacuum chamber side, are mixed, and said mixed raw material gases are supplied to the surface of a substrate, on which a film is to be formed, which is placed inside of the vacuum chamber in order to form a thin film on said substrate by means of vapor deposition, characterized in that it is provided with disk-shaped separator plates which are provided in the same number as that of the aforementioned pipes and used to receive the gases from the aforementioned respective pipes on their upper surfaces so as to distribute the gases evenly to multiple holes formed at regular intervals in the circumferential direction; a spacer which is used to create a first space where the gases coming out of the aforementioned multiple holes of said respective separator plates are mixed; a first rectifier plate with many small holes for rectifying the mixed gas in the aforementioned first space; a second mixing spacer which is used to create a second space where the mixing state of the gas coming out of said first rectifier plate is made uniform; a second rectifier plate with many small holes for rectifying the mixed gas in the aforementioned second space; and a retaining plate which is in the form of a annular body with a diameter smaller than the outside diameter of the aforementioned rectifier plate and used to hold all the elements provided between the aforementioned separator plate and the second rectifier plate, except at least the separator plate, in a stack close to the wall surface of the vacuum chamber or on a fixing element provided on the vacuum chamber side.

2. A method for manufacturing the gas introduction device for low-pressure CVD of Claim 1, characterized in that all the elements provided between the separator plate and the second rectifier plate are arranged coaxially in the order described in Claim 1, all of the separator plates are arranged tightly together in such a way that the multiple holes, which are formed on the respective separator plates at regular intervals in the circumferential direction for uniform distribution of the gases received on the upper surfaces of the separator plates, do not overlap in

the axial direction, and are held close to the wall surface of the vacuum chamber or on the fixing element provided on the vacuum chamber side using the annular retaining plate.

3. The gas introduction device for low-pressure CVD of Claim 1, characterized in that it is equipped with a annular base mount comprising a detachable camera mount which houses all the elements provided between the separator plate and the second rectifier plate coaxially when they are attached to the wall surface of the vacuum chamber or the fixing element provided on the vacuum chamber side while allowing all the elements provided at least between the first mixing spacer to the second rectifier plate to be inserted and removed in the axial direction and a retaining ring with camera mounts to be engaged with said base mount which is attached to/detached from the aforementioned base mount as it is rotated in order to serve as the annular retaining plate.

Detailed explanation of the invention

Industrial application field

The present invention pertains to a device for the introduction of raw material gases used in a low-pressure CVD for forming thin films on the surface of semiconductor substrates in a low-pressure film formation raw material gas atmosphere, wherein said raw material gases, which are introduced from multiple pipes for transporting different types of gases into a vacuum chamber maintained at low pressure, are mixed, said mixed raw material gases being supplied to the surface of a substrate, on which a thin film is to be formed, which is placed inside of the vacuum chamber in order to form a thin film on said substrate by means of vapor deposition, as well as to a method for manufacturing said gas introduction device.

Prior art

An example of this type of conventional gas introduction device from the prior art is shown in Figure 3. In this example, a plasma CVD device is used as the low-pressure CVD device, wherein, respective raw material gases A and B are introduced into a flat round buffer pocket formed on the front side of base electrode 4 through pipes 1 and 2 which penetrate the supporting part of base electrode 4 used to generate a plasma in vacuum chamber 3, where they are mixed together. Then, the mixed gases are supplied from shower electrode 5, in which many small holes are formed at regular intervals, to the surface of a substrate (also referred to as a wafer) 9 where a film is to be formed. Therefore, in this example, the gas introduction device comprises base electrode 4, shower electrode 5, and screws 8 are used to fasten them together.

When forming a thin film on the surface of wafer 9, after the wafer is heated by applying a voltage to heater 11, which is either built into or embedded in substrate table 10 on which wafer 9 is mounted, a high-frequency voltage is applied to base electrode 4 from RF power

supply 13 while supplying raw material gases A and B to the surface of wafer 9 from shower electrode 5 from pipes 1 and 2 in order to generate a plasma in the space between shower electrode 5 and wafer 9. Here, symbol 7 in the figure represents an insulating bushing which used to insulate the supporting part of base electrode 4 from vacuum flange 3b, and symbol 12 represents a motor which is used to adjust the gap between shower electrode 5 and wafer 9 to a desired value by moving substrate table 10 in the vertical direction via threaded rod 13.

Another example of a gas introduction device of the prior art is shown in Figure 4. In this example, buffer plate 16 is provided in the space created by base electrode 4 and shower electrode 5, so that the length of time of the mixing of the raw material gases before the mixed gas is spouted from shower electrode 5 is increased so as to promote more uniform mixing; here the raw material gases are supplied in the radial direction so as to make the pressure inside of the buffer pocket more uniform in order to achieve an even distribution of the flow rate over the surface.

Problems to be solved by the invention

In the case of the gas introduction device shown in Figure 3, many small holes are evenly distributed on the shower electrode; the raw material gases which have passed through pipes 1 and 2 come into direct contact with shower electrode, and although the buffer pocket is used for the purpose of spouting the raw material gases at a fixed pressure toward the wafer surface from the shower electrode, because the pressure is high near the electrode part where the gases are directly supplied, a larger amount of ingredients gases are spouted. As a result, the distribution of the film thickness over the wafer surface will be uneven during the formation of an ordinary thin film. In addition, as shown in Figure 4, even when the buffer plate is provided, and the raw material gases from the pipes are first directed to the buffer plate so as to scatter the gases in the radial direction in order to achieve a fixed pressure, the pressure distribution over the surface does not become sufficiently uniform. Thus, although the raw material gas mixing state can be improved relative to the case shown in Figure 3, the thickness distribution is still inadequate in that only a range of ±5% can be reliably achieved.

Another problem of the gas introduction devices shown in Figures 3 and 4 is the adhesion of a film on the shower electrode during thin film formation. That is, a film adheres to the shower electrode as the thin film is formed and blocks the small holes for spouting the raw material gases. Also, particles are formed from the film adhering to the shower electrode as it decomposes and contaminate the substrate on which the film is to be formed. Thus, the shower electrode must be cleaned periodically. Conventionally, the shower electrode is fixed at its peripheral part using four or more screws as shown in Figure 3, so that it takes a relatively long time to remove it. In addition, these screws are usually small Allen screws or bolts, with a hole for a screwdriver or a

wrench provided in the head. These holes sometimes become filled with the aforementioned film, which makes it difficult to remove the screws as it becomes difficult to fit the screwdriver. This too takes a long time, making the use of screws problematic.

The purpose of the present invention is to present a gas introduction device with which the raw material gases spouted from multiple pipes can be mixed more uniformly, and the distribution of the mixed gas spouted onto a substrate surface to be treated can be made uniform over the surface, as well as a method for manufacturing said device.

Means to solve the problems

In order to solve the aforementioned problems, in the present invention, a gas introduction device in which raw material gases, which are introduced from multiple pipes for transporting different types of gases into a vacuum chamber maintained at a low pressure, either through a wall surface of said vacuum chamber or through a fixing element provided on the vacuum chamber side, are mixed, and said mixed raw material gases are supplied to the surface of a substrate, on which a film is to be formed, which is placed inside of the vacuum chamber in order to form a thin film on said substrate by means of vapor deposition is characterized in that it is provided with disk-shaped separator plates which are provided in the same number as the aforementioned pipes and are used to receive the gases from the aforementioned respective pipes on their upper surfaces so as to distribute the gases evenly to multiple holes formed at regular intervals in the circumferential direction; a spacer which is used to create a first space where the gases coming out of the aforementioned multiple holes of said respective separator plates are mixed; a first rectifier plate with many small holes for rectifying the mixed gas in the aforementioned first space; a second mixing spacer which is used to create a second space where the mixing state of the gas coming out of said first rectifier plate is made uniform; a second rectifier plate with many small holes for rectifying the mixed gas in the aforementioned second space; and a retaining plate which is in the form of a annular body with a diameter smaller than the outer diameter of the aforementioned rectifier plate and used to hold all the elements provided between the aforementioned separator plate and the second rectifier plate, except at least the separator plate, in a stack close to the wall surface of the vacuum chamber or on a fixing element provided on the vacuum chamber side. To manufacture said device, all the elements provided between the separator plate and the second rectifier plate are arranged coaxially in the order described in Claim 1; all of the separator plates are stacked together tightly in such a way that the multiple holes, which are formed on the respective separator plates at regular intervals in the circumferential direction for even distribution of the gases received on the upper surfaces of the separator plates, do not overlap in the axial direction, and are held close to the wall surface of the vacuum chamber or on the fixing element provided on the vacuum chamber side using a

retaining plate in the form of a annular body. Also, it is preferred that said device be equipped with a annular base mount having a detachable camera mount which houses all the elements provided between the separator plate and the second rectifier plate coaxially when they are attached close to the wall surface of the vacuum chamber or on the fixing element provided on the vacuum chamber side while allowing all the elements provided at least between the first mixing spacer to the second rectifier plate to be inserted and removed in the axial direction and a retaining ring with camera mounts to be engaged with said base mount which can be attached to/detached from the aforementioned base mount as it is rotated in order to serve as a retaining plate in the form of a annular body.

Operation

When the gas introduction device has the aforementioned constitution, the multiple holes formed on the respective separator plates at regular intervals in the circumferential direction are evenly distributed in the circumferential direction when viewed from the axial direction. Thus, the respective raw material gases of different types received on the upper surfaces of the respective separator plates are evenly distributed in the circumferential direction when they are spouted into the first space; they are mixed evenly in the first space as they move toward the central part of the space; and the pressure inside said space is increased to a fixed value. Then, the mixture of the raw material gases created inside of the first space is spouted into the second space as it is divided into laminar flows in the same number as the small holes with the same diameter which are evenly distributed on the first rectifier plate. There, the gases are mixed while filling the space between the areas of the gases spouted from the respective small holes so as to increase the pressure inside of the space to the fixed value while further increasing the mixing uniformity. Said mixed gas sent from the second rectifier plate, on which many small holes with the same diameter are evenly distributed, is further divided into flows by the small holes, spouted to the substrate surface where the film is to be formed, and led to the substrate surface at a fixed, uniform flow rate distribution over the surface while increasing the mixture uniformity in the space on the front side of the substrate.

In addition, the detachable gas introduction device is a device that is equipped with a annular base mount having a detachable camera mount which coaxially houses all the elements provided between the separator plate and the second rectifier plate when they are attached close to the wall surface of the vacuum chamber or on the fixing element provided on the vacuum chamber side while allowing all the elements provided at least between the first mixing spacer to the second rectifier plate to be inserted and removed in the axial direction and a retaining ring with camera mounts to be engaged with said base mount which is attached to/detached from the aforementioned base mount as it is rotated in order to serve as the annular retaining plate. During

the manufacture of the device, after the separator plate is attached airtight either to a wall surface of the vacuum chamber or to the fixing element provided on the vacuum chamber side, the base mount is attached to the wall surface of the vacuum chamber or the fixing element provided on the vacuum chamber side, the remaining components are coaxially housed in said base mount, the camera mounts of the base mount are fitted to the camera mounts of the retaining ring, and the retaining ring is rotated to attach them to the base mount. In addition, the components can be easily detached for the purpose of maintenance simply by rotating the retaining ring, so that the maintenance time can be significantly reduced relative to conventional devices which require the removal of many screws. In addition, the screws used to attach the base mount to the wall surface of the vacuum chamber or the fixing element provided on the vacuum chamber side are covered by the retaining ring, so that the film never adheres to the screws, and the base mount can be easily removed when so required.

Application example

An application example of the configuration of the gas introduction device in accordance with the present invention is shown in Figure 1 in the form of an exploded perspective view, and the overall configuration of a film formation processing part of a low-pressure CVD device which contains said device is shown in Figure 2. First, the overall configuration of said film formation processing part will be explained using Figure 2.

Vacuum chamber 43 is configured with chamber main body 43a, upper flange 43b, and lower flange 43c as primary components. Substrate table 10 is connected to lower flange 43c via bellows 15 in such a way that it can be moved up and down, and it is driven linearly in the vertical direction by a not-shown drive motor (refer to symbol 12 in Figure 3). A concave surface which matches the outer diameter of wafer 9 is formed on the upper surface of substrate table 10 in order to mount wafer 9 at a prescribed position. Wafer 9 can be moved in and out as required using a wafer carrier device (not shown) by opening a gate valve provided between chamber main body 3a and a load/lock chamber (not shown). Table 44 is attached to upper flange 43b via insulating ring 14. Pipes for transporting raw material gases are attached to the upper surface of said table 44 in the same number as the types of the raw material gases used, two pipes, 1 and 2 in this case, via an insulator. Raw material gases 17 and 18 are supplied from separate gas reservoirs, respectively. Pipes 1 and 2 and table 44 are hermatically-sealed using an O-ring, and through-holes are formed on table 44 in order to allow raw material gases 17 and 18 to pass. Here, raw material gas 17 which passes through pipe 1 will be referred to as gas A, and raw material gas 18 which passes through pipe 2 will be referred to as gas B for the sake of the explanation of gas introduction device.

Terminal conductor 45, which is to be connected to an RF power supply in order to generate a plasma discharge, is attached to table 44. A separator plate, a first mixing spacer, a first rectifier plate, a second mixing spacer, and gas introduction device 100 configured with a second rectifier plate which constitutes shower electrode 31, which will be explained below, are attached to the vacuum side of table 44. Table 44 is hermatically sealed to vacuum chamber 43 using an O-ring, and the interior of vacuum chamber 43 is evacuated using a vacuum pump, which is provided separately.

Here, the film formation procedure performed in the aforementioned film formation processing part will be explained briefly.

The interior of vacuum chamber 43 is pumped down, and a wafer is mounted on the upper surface of substrate table 10 using a wafer transport device, which is provided separately. Substrate table 10 is preheated to a prescribed temperature, for example, 400° C, in order to heat wafer 9. Once the wafer is mounted on the upper surface of substrate table 10, said substrate table 10 is raised by a vertical driver and stopped when a prescribed height is reached with respect to shower electrode 31. Once wafer 9 is heated to the prescribed temperature, a voltage at high frequency, for example, 13.56 MHz, is applied from the RF power supply to table 44 through terminal conductor 45. Then, as prescribed raw material gases A and B are introduced through pipes 1 and 2 and pass through the gas introduction device, the raw material gases mix and rectified at a constant pressure are spouted from shower electrode 31. As a result, a plasma is generated from the activated raw material gases, and a film is formed on the surface of wafer 9. After the raw material gases are supplied for a prescribed amount of time, the film formation process is ended.

The gas introduction device will now be explained.

In Figure 1, 2 separator plates 20 and 21, which are used to distribute gases A and B received on their upper surfaces in the radial direction, are assembled and held on table 44, which serves as the assembly base, using attachment screw 22. Grooves 23 with an appropriate width are formed in a radial pattern on separator plate 20 in the radial direction from its center, and through-holes 24 are formed at the peripheral part so as to form paths for gas A to flow through. Similarly, a round groove and grooves which extend in a radial pattern from said round groove in the radial direction are also formed on separator plate 21 in the same number as the grooves formed on separator plate 20, and through-holes 26 are formed at the ends of said grooves. In addition, a small hole, which is used to lead gas A to the upper surface of separator plate 20, is formed at the center of separator plate 21. Then, hole 27, which is used to allow gas B from separator plate 21 to pass down, is formed in separator plate 20.

First mixing spacer 28 will now be explained. This spacer is provided in order to create a space where gas A, which passed through separator plate 20, and gas B, which passed through

separator plate 21, are mixed evenly. After gas A and gas B are divided through the multiple holes formed in the radial direction of separator plate 20 and separator plate 21, they are introduced into a space formed by separator plate 21, first mixing spacer 28, and first rectifier plate 29, to be described below. They are mixed together there and the pressure inside of the space is increased to a prescribed level.

Small holes, for example, with a diameter of 0.5 mm, are arranged evenly on first rectifier plate 29 at a high level of precision. First rectifier plate 29 divides the mixed raw material gas mixed in the aforementioned space into flows which pass through the small holes in order to create a laminar flow. A 1-mm to 3-mm high space is formed between first rectifier plate 29 and second rectifier plate 31 using the second mixing spacer 30; the raw material gases which flowed there in the form of laminar flows are uniformly mixed to attain a constant pressure level and spouted in the form of laminar flows through the small holes, for example, with a diameter of 0.5 mm, formed on second rectifier plate 31.

First mixing spacer 28 and second mixing spacer 30 are formed to have the same dimension in the radial direction while their inner diameter is slightly greater than the outer diameter of separator plates 20 and 21. Thus, second rectifier plate 31, second mixing spacer 30, first rectifier plate 29, and first mixing spacer 28 are assembled together coaxially when they are brought into contact with table 44. In addition, the inner circumferential surface of base mount 32, which houses elements 31, 30, 29, and 28, is of a size that it comes in close contact with said elements over the entire outer circumferential surfaces of said elements in order to prevent the raw material gases from flowing out from the outer circumferential surface side of the aforementioned elements; and the base mount is attached to table 44 using attachment screw 33.

Base mount 32 is provided with three claw-like camera mounts 35 which are often used for a lens camera. Retaining ring 34, which is combined with base mount 32 so as to support the rim part of second rectifier plate 31 while preventing the elements provided between second rectifier plate 31 and first mixing spacer 28 from slipping off, is provided with groove-like camera mounts 36 which engage with the claw-like camera mounts of base mount 32; and a ring groove for housing claw-like camera mounts 35 is formed at its edge part in the axial direction. Therefore, retaining ring 34 is held to base mount 32 by rotating retaining ring 34 after groove-like camera mounts 36 of retaining ring 34 are engaged with claw-like camera mounts 35 of base mount 32 in order to prevent the upper elements, including second rectifier plate 31 which constitutes the shower electrode, from falling out.

Furthermore, although a plasma CVD device is used as the low-pressure CVD device to which the gas introduction device of the present invention is attached in the explanation above, the gas introduction device of the present invention can, of course, be applied to a thermal CVD device. In addition, needless to say, it can be utilized as a gas introduction device which is used

to achieve a uniform surface distribution of the raw material gases over the wafer surface when they are pre-mixed and supplied from 1 pipe.

Effect of the invention

As explained above, in the present invention, because the gas introduction device is configured using the aforementioned elements and is manufactured according to the aforementioned method, the surface distribution of the raw material gases spouted from said device can be made uniform, resulting in far more uniform mixing state of the raw material gases than before, so that the film thickness distribution of the thin film formed on the wafer surface is within 3% without compromising the film formation rate. In addition, because the replacement of the second rectifier plate, whose surface formerly became contaminated during the film formation process, is realized through the attachment/detachment of the camera mount type retaining ring, the attachment screws of the prior art is no longer needed, so that the maintenance time can be reduced, and the problems associated with disassembly are solved.

Brief description of the figures

Figure 1 is an exploded perspective view of a gas introduction device in accordance with an application example of the present invention. Figure 2 is a cross-sectional side view showing an example of the overall configuration of the film formation processing part of a low-pressure CVD device to which the gas introduction device shown in Figure 1 is attached. Figure 3 and Figure 4 show a full and partial cross section, respectively, of examples of different configurations of conventional gas introduction devices.

1, 2 : pipes; 3, 43: vacuum chamber; 6, 100: gas introduction device; 9: substrate on which a thin film is to be formed (wafer); 17: gas A (raw material gas); 18: gas B (raw material gas); 20: separator plate (for gas A); 21: separator (for gas B); 28: first mixing spacer; 29: first rectifier plate; 30: second mixing spacer; 31: second rectifier plate (shower electrode); 32: base mount; 34: retaining ring; and 35, 36: camera mounts.

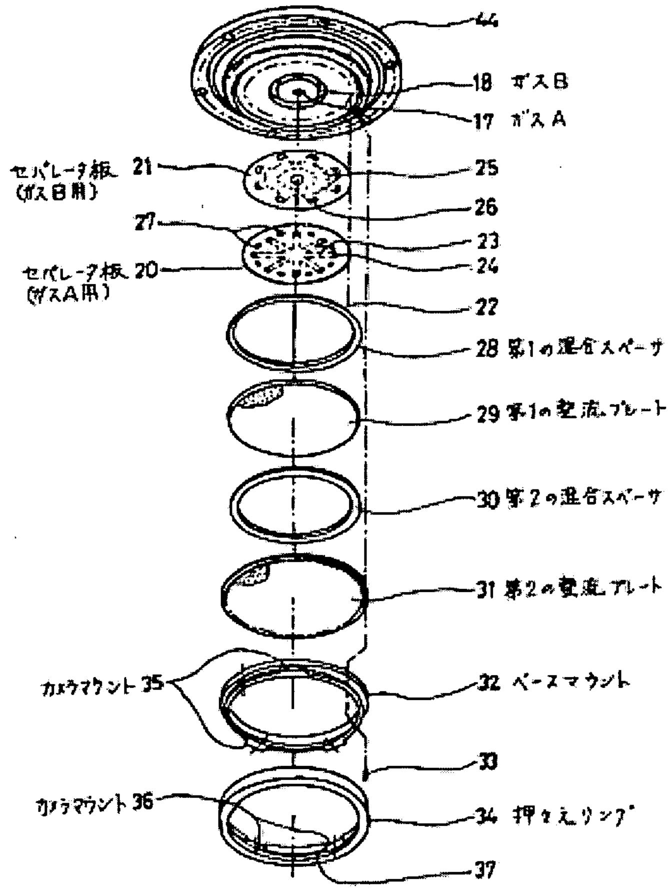

Figure 1

Key:

Key:	17	Gas A
	18	Gas B
	20	Separator plate (for gas A)
	21	Separator (for gas B)
	28	First mixing spacer
	29	First rectifier plate
	30	Second mixing spacer
	31	Second rectifier plate
	32	Base mount
	34	Retaining ring
	35, 36	Camera mounts

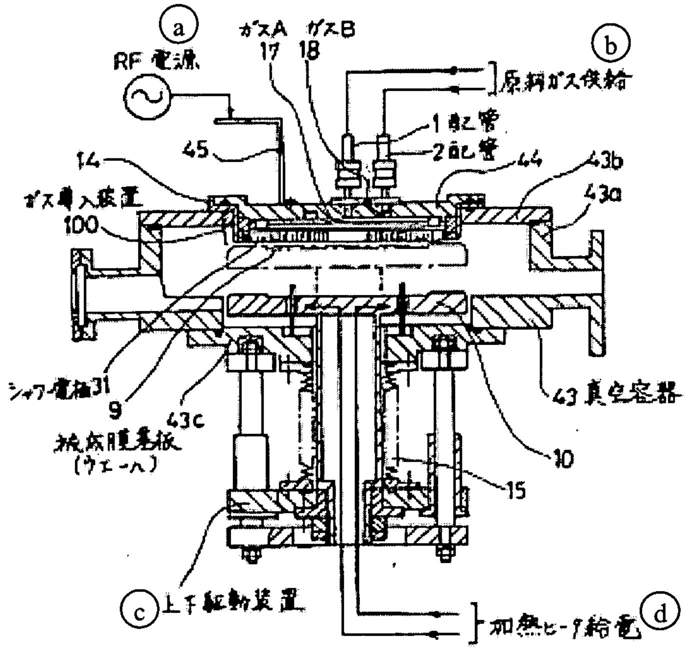

Figure 2

Key:

a	RF power supply
b	Supply of raw material gases
c	Vertical driver
d	Voltage supplied to heater
1, 2	Pipes
9	Substrate on which a thin film is to be formed (wafer)
17	Gas A
18	Gas B
31	Shower electrode
43	Vacuum chamber
43c	Lower flange
100	Gas introduction device

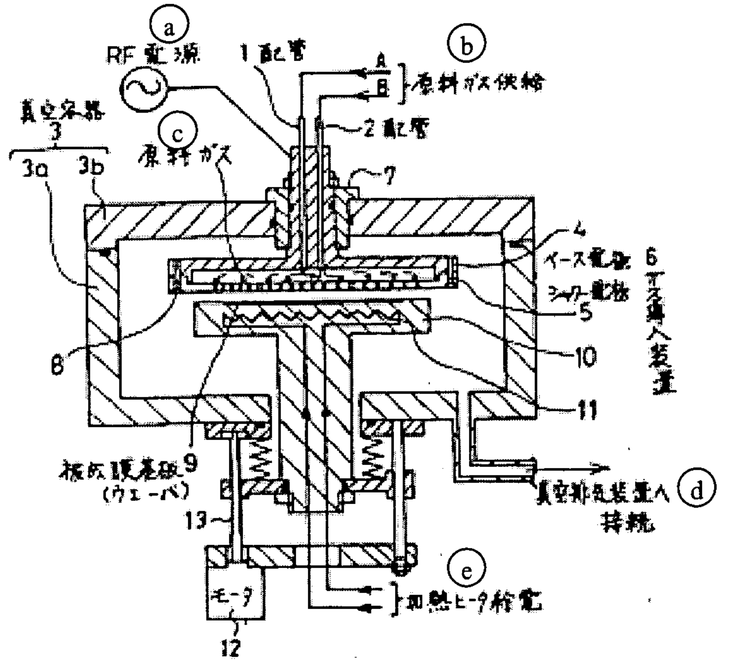

Figure 3

Key: a RF power supply
b Supply of raw material gases
c Raw material gas
d Connected to pumping device
e Voltage supplied to heater
1, 2 Pipes
3 Vacuum chamber
4 Base electrode
5 Shower electrode
6 Gas introduction device
9 Substrate on which a thin film is to be formed (wafer)
12 Motor

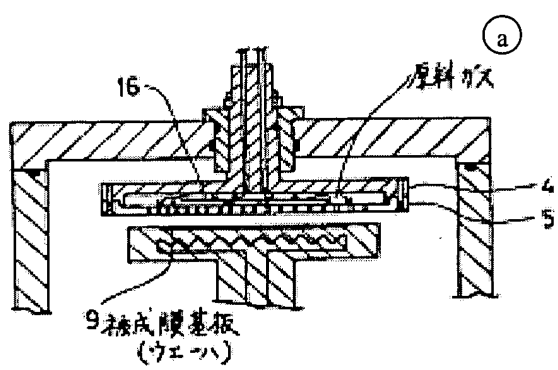

Figure 4

Key: a Raw material gas
9 Substrate on which a thin film is to be formed (wafer)